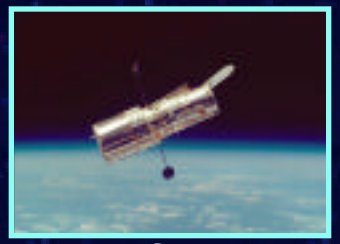
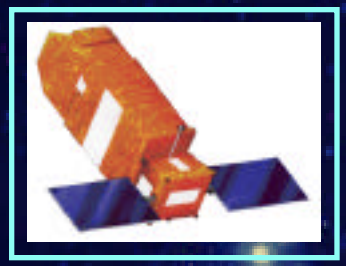
Astronomical Search for Origins

The Missions

Telescopes

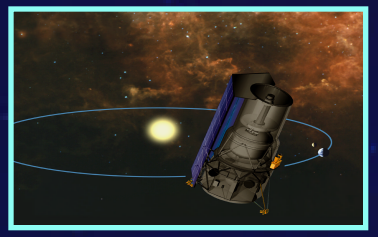


HST



FUSE

SOFIA



SIRTF

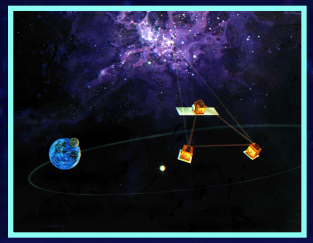
WIRE

NGST

Interferometers

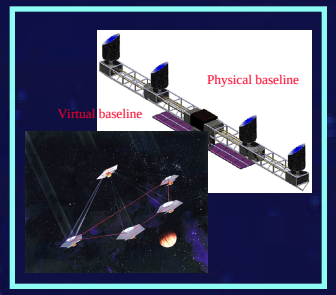
PTI

Keck

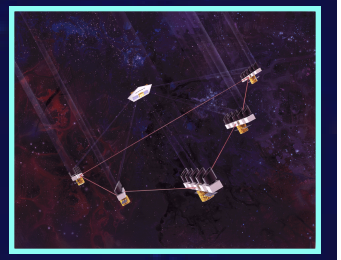


DS-3

SIM



TPF



PI

HST

Hubble Space Telescope

http://www.stsci.edu/hst/

Salient Features

- A 2.4 m optical astronomical observatory and its intruments operating above the Earth's atmosphere
  - 600 km low Earth orbit; 97-minute orbit
  - 15.9 m long; 4.2 m in diameter; 11,000 kg
  - Wavelength range: 0.1 to 2.5 microns
- First long-term, maintainable and repairable space observatory − a NASA/European Space Agency partnership
  - International general user facility
  - Over 300 guest observer proposals executed yearly

Science

- Spectacular Near Infrared Camera and Multi-Object Spectrometer (NICMOS) early release observations and great continuing science returns; however,
  - NICMOS will have a shorter life than planned (approximately 1.7 years vs. 5 years)
    - NICMOS observing programs to be increased during the next 18 months to partially compensate
    - Potential to extend life indefinitely with a cooling system to be installed during Third Servicing Mission
  - 1 of 3 NICMOS cameras not confocal with primary optics
    - A temporary change of the secondary mirror will allow campaigns for this camera
- Development underway for 1999 Third Servicing Mission
  - The Advanced Camera for Surveys (ACS) is being developed by Johns Hopkins University
  - A new solar array, fine guidance sensor, and advanced computer will be installed

HST

Highlights over the past six months

- Servicing mission operations verification for NICMOS is completed, and the instrument has been commissioned for science operations
- Over 400 proposals were received on for NICMOS observations. NICMOS utilization is being predicted at 40-50% of HST observing opportunities through the life of the cryogen (estimated at 17 months)
- Competition and selection of instrument for 2002 shuttle servicing mission: Cosmic Origins Spectrograph (COS), Univ. of Colorado and Ball Aerospace

Highlights for the next six months

- Continuation of study for cooling system to recover near-full capabilities of NICMOS
- Continuation of science observations
- December campaign using NICMOS Camera-3 planned (requires re-focusing of telescope)

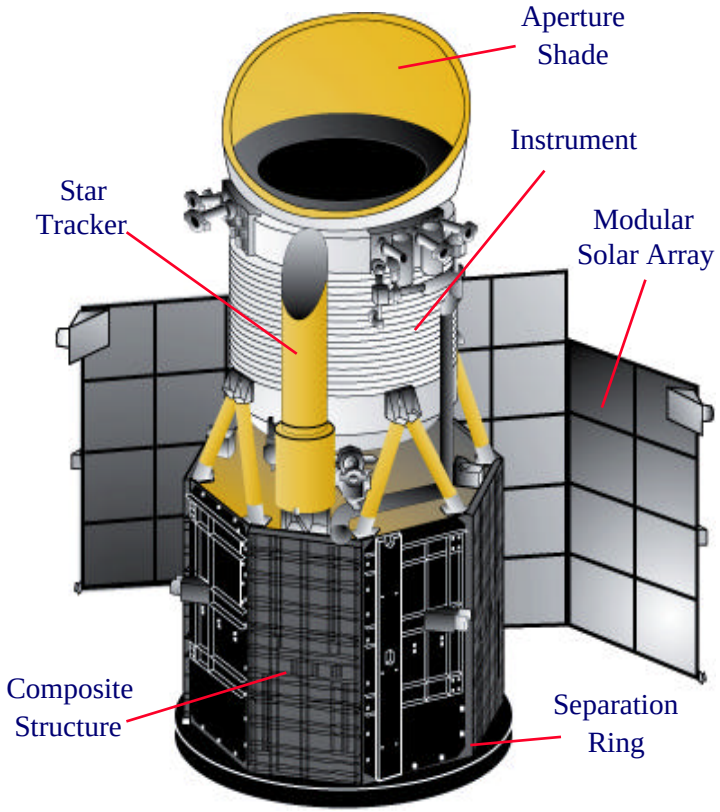
WIRE

Wide-field Infrared Explorer

http://www.ipac.caltech.edu/wire/

Salient Features

- A cryogenically-cooled, two-color (12 μm & 25 μm) infrared imaging telescope
- A 30 cm Ritchey-Chretien Cassegrain telescope
- Two 128x128 pixel, arsenic-doped silicon, Blocked Impurity Band (BIB) focal plane arrays at 12 μm & 25 μm
- Dual stage 7K/12K solid hydrogen cryostat
- Lifetime: 4-6 months
- Launch Date: 9/15/98



Science

- WIRE will study the evolution of starburst galaxies and search for protogalaxies. The primary scientific objectives are to answer the following three questions:
  - What fraction of the luminosity of the Universe at a redshift of 0.5 and beyond is due to the starburst galaxies?
  - How fast, and in what way, are starburst galaxies evolving?
  - Are luminous protogalaxies common at redshifts?

WIRE

Highlights over the past six months

- Flight cryostat delivered to USU/SDL for instrument build-up.
- Flight 12 μm & 25 μm Focal Plane Arrays (FPAs) completed.
- Flight telescope build-up in process.
- Spacecraft primary composite structure being readied for delivery to GSFC.
- Solar array qualification modules delivered.
- Completion and selection of Associate Investigator (AI) program.

Highlights for the next six months

- Flight structure delivery: 9/97
- Spacecraft I&T: 9/97
- Instrument flight electronics delivery: 12/97
- Second hydrogen load of cryostat: 2/98
- Spacecraft environmental testing: 2/98
- Introduction of AI program into WIRE science program

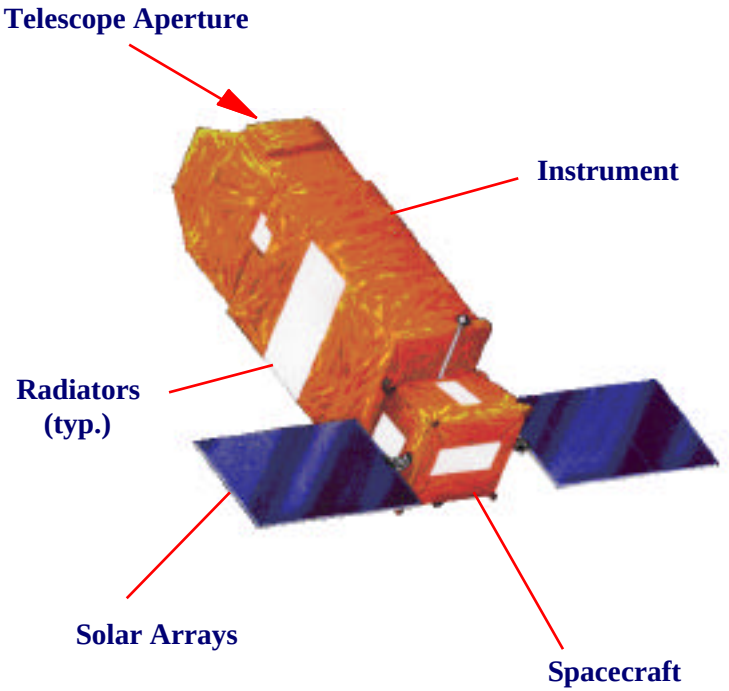
FUSE

Far Ultraviolet Small Explorer

http://fuse.pha.jhu.edu/

Salient Features

- A far-ultraviolet spectroscope comprised of
  - Four co-aligned telescopes
  - Four high resolution, aberration corrected holographic diffraction gratings
  - Two delay-line microchannel plate detectors
- Wavelength coverage: 910-1180 Å
- Spectral coverage: better than .05 Å with a goal of .03 Å
- Lifetime: three years
- Launch Date: 9/98



Science

- FUSE will use high-resolution, far-ultraviolet spectroscopy to study physical processes governing three broad areas of astrophysics
  - Origin and evolution of light elements in the early universe
  - Processes controlling the evolution of galaxies
  - Origin and evolution of stars and planetary systems
- Guest Observer Program: 75% first year, 45% second year, 60% third year

FUSE

Highlights over the past six months

- Spectrograph integration, alignment and calibration underway
- Spacecraft integration underway
- Control center facility completed: Johns Hopkins University, Baltimore campus
- Ground station antenna assembled; ready for testing
- Spectrograph integration (started in 1/97)
- Spacecraft integration (started in 5/97)

Highlights for the next six months

- Start spacecraft testing: 9/97
- Start satellite integration: 3/98
- Start satellite environment tests: 4/98
- Ship satellite to Cape Canaveral: 8/98
- Launch readiness: 9/98

SOFIA

http://sofia.arc.nasa.gov/

Stratospheric Observatory for Far-Infrared Astronomy

Salient Features

- 2.5-meter, airborne telescope optimized for mid-to-far-IR observations with multiple instruments
- Wavelength range 0.3μm to 1600 μm
- Stratospheric operation for over 8 hours per mission, 960 hours per year; 20+ years lifetime
- Image quality: 1.5 arcsec at 3-10 μm
- "First Flight" in October 2001
- Collaboration with German Space Agency

Science

- Interstellar cloud physics and stellar birth in our galaxy
  - Importance of magnetic fields and cloud rotation
- Protoplanetary disks and planet formation in nearby star systems
- Origin and evolution of biogenic atoms, molecules and solids
  - Environments hospitable to prebiotic molecules
- Composition and structure of comets, planetary atmospheres and rings
  - Solar nebula composition and solar system evolution
- The dynamic activity at the center of the galaxy
  - Power sources and similarity to active galactic nuclei
- Luminosity mechanisms, dynamics, and interstellar processes in other galaxies

SOFIA

Highlights over the past six months

- All development plans, teams, tools and processes in place and functioning
- 747SP aircraft acquired and furnished to prime contractor team for modification
- Primary mirror blank fabricated in Germany
- Requirements Review completed for DARA Telescope Assembly
- Integrated Baseline Review completed for USRA/team contract
- Draft US/German interface control documents executed
- First NASA Independent Annual Review conducted
- Instrument proposals received and reviewed in mid-July

Highlights for the next six months

- US System/Observatory-Level System Requirements Review completion
- Telescope Assembly System Definition Review accomplishment
- Conduct of 747 baseline flight tests
- Final high-speed, wind tunnel testing and downselect of cavity door candidates
- Science and mission operations center (hangar modification) PDR completion
- Initial suite of instruments selected in mid-September
- SOFIA instrument grants initiated

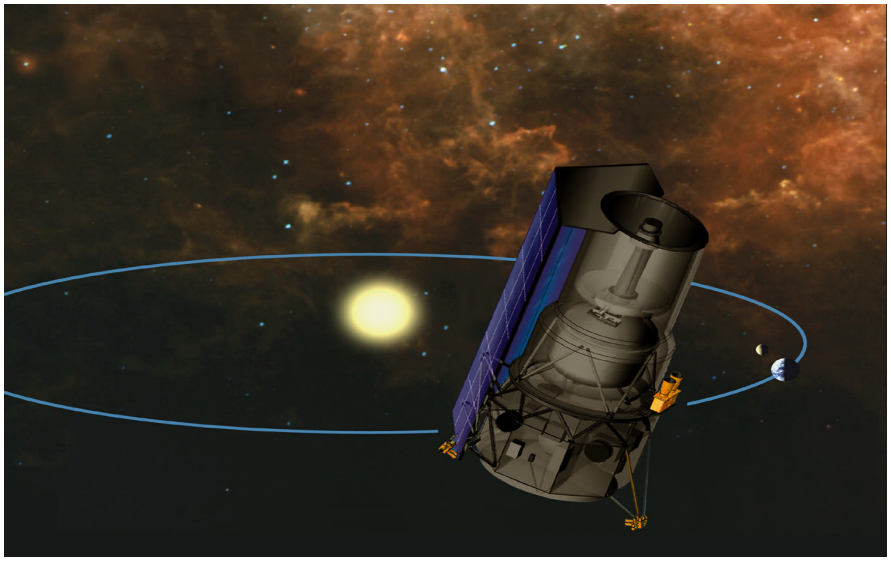
SIRTF

Space Infrared Telescope Facility

http://sirtf.jpl.nasa.gov/sirtf/home.html

Salient Features

- Heliocentric orbit trailing the Earth
- 85 cm Beryllium telescope operating at 5.5 K
- 3 instruments with 3-180 micron wavelength coverage operating at 1.5 K
- Launch date: December 1, 2001
- Operational life: 2.5 years, goal 5 years
- Observing time available to scientific community: 80%



Science

- To search for brown dwarfs and super-planets, and to understand the contribution of sub-stellar objects to the mass of the Galaxy.
- To study protoplanetary and planetary debris disks, and to assess the frequency of solar-system formation around nearby solar-type stars.
- To determine properties of ultra-luminous galaxies and active galactic nuclei, both nearby and in the distant Universe, and to understand the mechanisms which power these extreme energetic objects.
- To study normal galaxies as they were when the Universe was less than one-quarter of its current size and age, and to understand how galaxies have evolved with cosmic time.

SIRTF

Highlights over the past six months

- SIRTF baseline revised to capabilities of Delta 7920H: larger capacity = larger lifetime.
- SIRTF Science Requirements Document issued.
- SIRTF Nominal LHe Lifetime increased to 5 years.
- Observatory Requirements Review held February 27-28, 1997.
- Intense effort in replanning and recosting the FY ‘98-’02 activities resulted in a viable plan which will meet the $450 million funds that are available.
- Mission operations (Phase E) plan was presented to NASA Hq on June 25, 1997.
- Completed first assembly of the SIRTF telescope at Ball Aerospace in preparation for cryogenic testing at JPL.

Highlights for the next six months

- Cryo-cycle the Silicon Carbide Test flat.
- Cryogenically test the all-Beryllium telescope assembly.
- Conduct subsystem peer reviews in preparation for the SIRTF/PDR/NAR.
- Conduct SIRTF PDR/NAR, September 23-25, 1997.
- Receive approval to start Phase C/D before April 1998.
- Place purchase orders for long-lead components.
- Proceed with detailed design of system/subsystem elements.

NGST

Next Generation Space Telescope

http://ngst.gsfc.nasa.gov/

Salient Features

- Near-infrared telescope with an 8-m class aperture
- Optimized for 1-5 μm (goal of 0.5-30 μm)
- Passive cooling < 50 K
- Possible orbits: L2, 3 AU, or above the ecliptic
- Wide-field camera and multi-object spectrograph
- Zodiacal-background-limited detector sensitivity
- 5-year lifetime (10-year goal)

Science

- NGST will provide major pieces of the puzzle currently missing from the picture of the Universe evolution from the Big Bang to the current epoch
  - NGST will
    - See the first stars and galaxies
    - Determine the shape of the Universe and shed light on its eventual fate
    - Map the chemical evolution of the Universe by observing the first supernovae
    - Observe debris disks around nearby stars

NGST

Highlights over the past six months

- Awarded contracts for system architecture studies to TRW and Ball Aerospace
- Awarded contracts for large prototype ultra-lightweight (less than 15 kg/m^2) cryogenic mirrors
- Published "*NGST: Visiting a Time When Galaxies Were Young*," documenting basic requirements and early study results

Highlights for the next six months

- Convene a non-advocate Standing Review Board to examine NGST program execution and plans
- Award contracts for breadboard cryogenic actuators and scientific instrumentation studies
- Fabricate segmented primary mirror for ground testbed to demonstrate phasing and active wavefront control of a segmented telescope system

PTI

Palomar Testbed Interferometer

http://huey.jpl.nasa.gov/palomar/

Salient Features

- Testbed for Keck Interferometer
  - Designed to demonstrate:
    - Sub-100 μas/hr astronomy and,
    - High dynamic range imaging
- 110-meter baseline
- Wavelength range: 1.5 to 2.4 μm
- Simultaneous fringe detection on two nearby stars
- "First Fringe" in July 1995

Technical Demonstration for Keck Interferometer

- Increase the sensitivity of ground-based IR interferometers by a factor of ~ 1000,
  - By "phase reference" interferometry which increases the coherent integration time from 10 msec to ~ 500 sec.
- Demonstrate sub-100 μas ground-based, narrow-angle astronomy (versus ~ 1 mas with a single aperture telescope)

Science

- Diameter of dust disks in star/planetary system-forming regions at 0.01 arcsec resolution
- Survey ~ 30 nearby stars for ~ 1/10 Jupiter mass planets in ~ 10-year orbits
- Survey of binarity in star formation regions
- Study of pulsating variable stars
- Some guest observer opportunities

PTI

Highlights over the past six months

- Demonstrated narrow angle astrometry at an accuracy of 200 ~ 300 μas for short (~ 200-second) integration times.
  - Consistent with the goal of ~ 70 μas/hr
- Installed accelerometer feed forward system to "cancel" telescope vibrations from a few microns to below 100 nanometers.
  - This technique will be applied to both Keck and SIM.
- Installed single mode fiber fringe detection system to improve instrument visibility from ~ 40% to ~ 90% and improve dynamic range from ~ 20:1 to ~ 100:1 for greater contrast ratio in close binaries.
- The interferometer is now sufficiently automated and debugged so that a single observer can operate the instrument at night.

Highlights for the next six months

- Install and align optics in a 3rd siderostat to create a second baseline
  - Two baselines are needed to conduct an astrometric survey of ~ 30 nearby stars for planets to ~ 1/10 Jupiter mass.
- Install the 1.6 μm channel to enable a series of observational modes
  - Extends high-dynamic range imaging from 100:1 dynamic range to 1000:1.
    - This technique at Keck will be extended another order of magnitude to perform direct detection of "hot" Jupiters (7 to 9 "exoplanets" discovered to date are "hot" Jupiters).
  - Improve central fringe ID needed for narrow angle astrometry
- Verify that installation of vacuum pipes (between central building and telescope) reduces the 1/f noise and demonstrate ~ 70 μas accuracy in 1 hour of integration.

Keck Interferometer

http://huey.jpl.nasa.gov/keck/

Salient Features

- The two 10-m Keck telescopes + four to five 2-m class outrigger telescopes
- 85-meter baseline between the two Kecks
- Wavelength: 2 μm and 10 μm
- Imaging resolution: 5 mas at 2 μm
- Astrometric accuracy: 10 μas
- First light
  - Two-element: mid-2000
  - Array: mid- 2002

Science

- Direct detection of brown dwarfs and warm Jupiters (Jupiter-mass planets in close orbits)
- Null the star and study zodiacal clouds around nearby stars
  - This data is needed for the TPF design
- Indirect detection of many Uranus-size planets via astrometry
- High-resolution imaging of disks in which planets may be forming

The first two objectives can be met with only the two Kecks connected as an interferometer.
The next two require the additional baselines provided by the outrigger telescopes.

Keck Interferometer

Highlights over the past six months

- Preliminary design, industry cost estimates, u-v plane coverage analysis, site layout with light pipe locations for outriggers
- Grass roots costing, Implementation Plan, Science Requirements, Web Page, Fact Sheet
- Started permitting process − lengthy process
- Preliminary Design Review: September 4-5, 1997

Highlights for the next six months

- Detailed design of beam combiner, transport optics, delay lines, dual star feed, laser metrology
- Obtain siderostat permits from State of Hawaii
- Start siderostat procurement
- Start construction of Keck I adaptive optics
- Get firm industrial bids on outrigger telescopes and domes
- Complete definition of operational infrastructure and data center

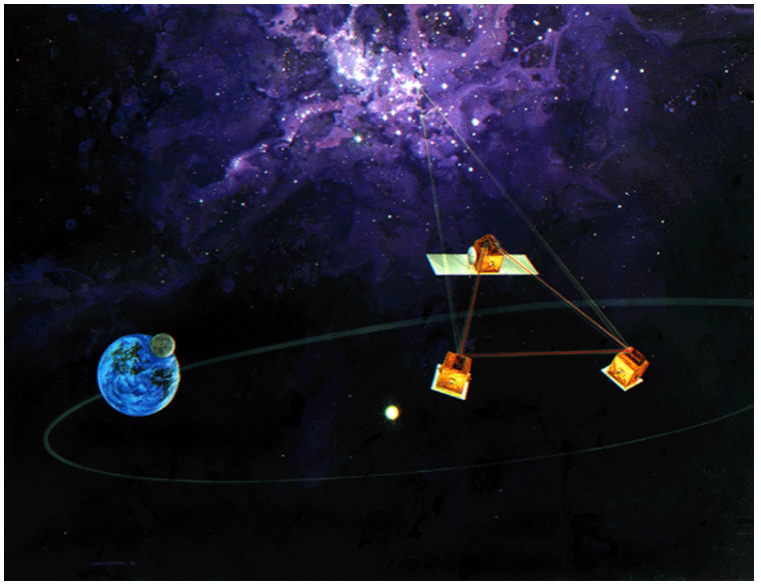
DS-3

http://huey.jpl.nasa.gov/nmi

Deep Space-3 (from the New Millennium Program)

Salient Features

- Optical Space Interferometer
  - Three S/C flying in formation
  - Two collectors, one combiner
  - 100 m to 1 km baseline
- Imaging resolution: 100 μas (at 1 km)
- Launch December ‘01
- Heliocentric orbit
- 6-month mission (baseline)



Technology

- Long baseline optical interferometry in space
  - Space validation of many H/W and S/W elements for SIM
- Precision formation flying (1 cm)
  - Applicable to TPF

Science (not primary objective of the mission)

- Tidal distortion of a star’s photosphere due to a black hole orbiting the star

DS-3

Highlights over the past six months

- DS-3 presented to Associate Administrator in April ‘97
  - Approval to proceed with concept refinement and costing
- Six-weeks study commissioned and completed; Detailed costing started
- Trip to Berlin to discuss potential cooperation with DLR and work out an agreement document
  - DLR enthusiastic − but funding availability still uncertain

Highlights for the next six months

- Cost workshop scheduled for September 17, 1997
- Technology transfer issues with Germany being worked
- Presentation to Associate Administrator in October
  - Anticipate approval and FY 98 project start
- Compile and integrate a set of analytical behavioral models
- Start the design of the DS-3 interferometry testbed
- Release the S/C RFP

SIM

Space Interferometry Mission

http://huey.jpl.nasa.gov/sim/

Salient Features

- Optical Space Interferometer with 10-m baseline
- Path Length Control: Nanometer class
- Path Length Knowledge: Sub-Nanometer class
- Imaging Resolution: 10mas
- Astrometric Accuracy: 4 μas wide angle; 1 μas narrow angle
- Launch date: mid-2005

Science

- Indirect detection of planets outside the Solar System through observation of thousands of stars.
- Improve on the best star positions in current catalog by a factor of 250 and extend the sensitivity to much fainter stars − application to ages and distances in the Universe.
- Very high resolution (10 mas) imaging of broad range of astrophysical phenomena
- Study structure of planetary dust disks using starlight nulling imaging.
- As co-equal objective to its science, SIM is also to be a technological pathfinder to the Terrestrial Planet Finder (TPF) mission.

SIM

Highlights over the past six months

- Completed industry pre-project studies (three teams) − results integrated into ongoing orbit and architectural trade studies
- Developed draft document of SIM Science Goals, Science Requirements and Science Floor
- Completed Micro-arcsecond Metrology Testbed (MAM) Design Review
  - A 1/5 scale model of SIM tested in vacuum
- IPEX-II experiment flown on STS-85 in August
  - Representative SIM structure used to study microdynamic structural behavior
- Budget profile established with NASA Hq based on an 2001 Phase C/D start, 2005 launch

Highlights for the next six months

- Phase A start (October 1, 1997)
- Initiate six-month Phase A study contracts with the three industry teams
- Complete Preliminary Interferometer Requirements Review
  - Use to establish baseline requirements for STB-3
    - A full scale three-baseline interferometer testbed
- Complete system level design for STB-3
- Spread the gospel of interferometry
  - Two-day Science Workshop in 10/97
  - AAS Special Session on SIM in 1/98
  - SPIE Conference on Astronomical Interferometry in 3/98

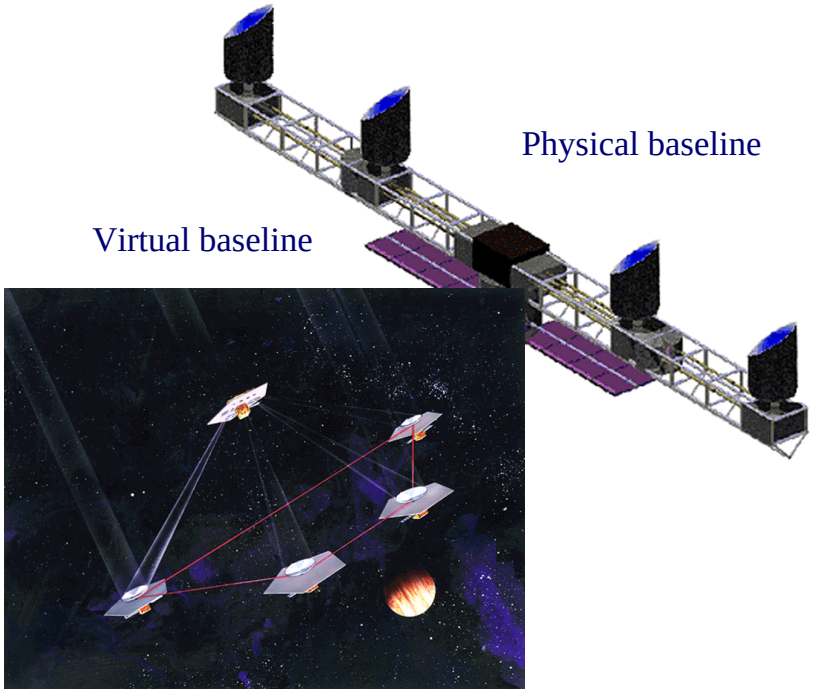
TPF

Terrestrial Planet Finder

http://origins.jpl.nasa.gov/missions/terrplfndr.html

Salient Features

- IR Interferometer (7-17 μm)
- Baseline: 75 m or longer, depending on exo-zodiacal levels
- Orbit: 1 AU - 5 AU
  - Higher background noise (local zodiacal clouds) for orbits closer to the Sun
- Telescope Apertures: 4-6 m at 1 AU or 1.5-2 m at 5 AU
- Mission Duration: 5 years of observing
- Operating Temperature: < 35 K for all optical elements



Science

- Find and characterize Earth-like planets around other stars
  - Search neighboring 1,000 star systems
  - Characterize brightest planets
  - Detect broadband (resolution ~ 5) Earth-like signals in 1 hour
  - Detect spectral features (resolution ~ 20) in < 1 week

TPF

Highlights over the past six months

- MIT contract let for system studies
  - Provides preliminary evaluation of breakpoints for physical vs. virtual baselines
- Three industrial contracts let for system studies
  - Provides preliminary configuration sizing/costing as “existence proof” for mission
- Science advisory team in place to advise on trades, performance, goals
  - Two meetings to date

Highlights for the next six months

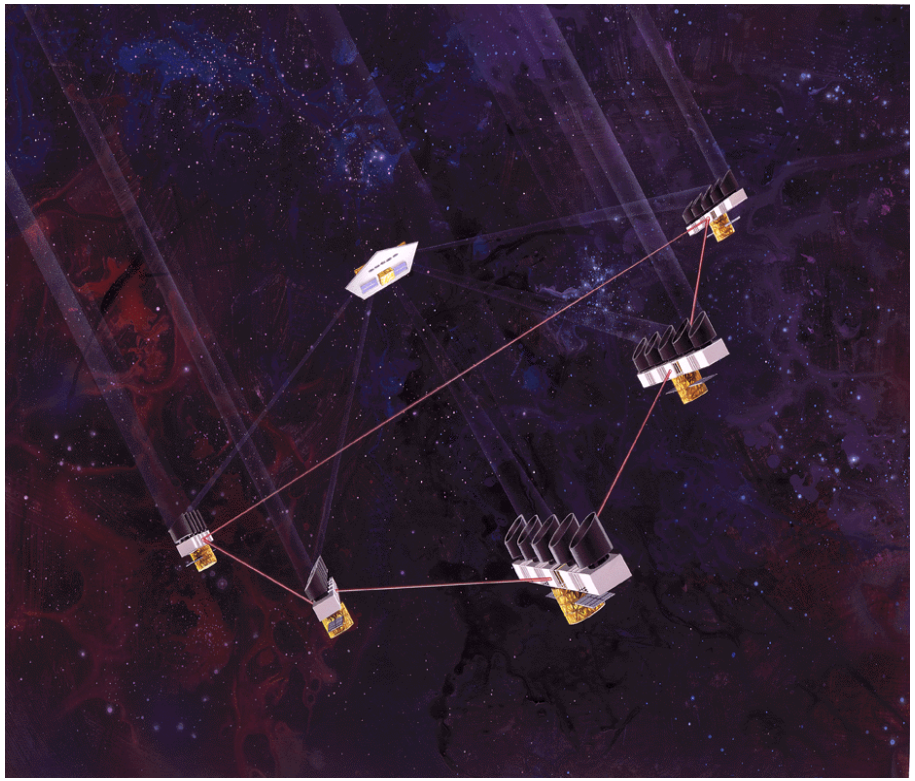
- Develop to the next level of detail the TPF technology roadmap
- Follow-on MIT contract with tasks evaluating baseline approaches
- Perform science performance/architectural studies
- Define applications of TPF as a general astrophysics observatory
  - Over and above the primary goal of planet detection/characterization
- Work with the science community and the ARC to start the definition of biological signatures for life detection
- Keep in touch with studies in Europe on potential future ESA Cornerstone mission − Darwin

Planet Imager

http://origins.jpl.nasa.gov/missions/planetimg.html

"Potential" Salient Features

- An array of TPF-class interferometers flying in formation
- Starlight nulled at each interferometer and relayed to a beam combiner S/C
- Each interferometer carries four 8-m telescopes to collect starlight and one 8-m telescope to relay collected light to the beam combiner S/C
- Total array baseline: 6000 km
- Total light collecting area: 1000 square meters
- Launch date: 20??



Science

- Humanity's first resolved image of another world

Planet Imager

Highlights over the past six months

- None

Highlights for the next six months

- No activities planned for the next several years